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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/031,024	03/28/2002	Albertus Cornelis Den Brinker	NL 000287	4469

7590 08/02/2005

Philips Electronics North America Corporation
Intellectual Property Department
580 White Plains Road
Tarrytown, NY 10591

EXAMINER	
PIERRE, MYRIAM	
ART UNIT	**PAPER NUMBER**
2654	

DATE MAILED: 08/02/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No. 10/031,024	Applicant(s) DEN BRINKER ET AL.	
	Examiner Myriam Pierre	Art Unit 2654	

-- *The MAILING DATE of this communication appears on the cover sheet with the correspondence address* --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *01/01/2002*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-17* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-17* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *28 March 2002* is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. EP0004599.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *06/17/02*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

DETAILED ACTION

Claim Objections

1. Specification is missing heading or labels. Please refer to Content of Specification below for further details:

Content of Specification

(a) Background of the Invention: See MPEP § 608.01(c). The specification should set forth the Background of the Invention in two parts:

(1) Field of the Invention: A statement of the field of art to which the invention pertains. This statement may include a paraphrasing of the applicable U.S. patent classification definitions of the subject matter of the claimed invention. This item may also be titled "Technical Field."

(2) Description of the Related Art including information disclosed under 37 CFR 1.97 and 37 CFR 1.98: A description of the related art known to the applicant and including, if applicable, references to specific related art and problems involved in the prior art which are solved by the applicant's invention. This item may also be titled "Background Art."

(b) Brief Summary of the Invention: See MPEP § 608.01(d). A brief summary or general statement of the invention as set forth in 37 CFR 1.73. The summary is separate and distinct from the abstract and is directed toward the invention rather than the disclosure as a whole. The summary may point out the advantages of the invention or how it solves problems previously existent in the prior art (and preferably indicated in the Background of the Invention). In chemical cases it should point out in general terms the utility of the invention. If possible, the nature and gist of the invention or the inventive concept should be set forth. Objects of the invention should be treated briefly and only to the extent that they contribute to an understanding of the invention.

(c) Brief Description of the Several Views of the Drawing(s): See MPEP § 608.01(f). A reference to and brief description of the drawing(s) as set forth in 37 CFR 1.74.

(d) Detailed Description of the Invention: See MPEP § 608.01(g). A description of the preferred embodiment(s) of the invention as required in 37 CFR 1.71. The description should be as short and specific as is necessary to describe the invention adequately and accurately. Where

elements or groups of elements, compounds, and processes, which are conventional and generally widely known in the field of the invention described and their exact nature or type is not necessary for an understanding and use of the invention by a person skilled in the art, they should not be described in detail. However, where particularly complicated subject matter is involved or where the elements, compounds, or processes may not be commonly or widely known in the field, the specification should refer to another patent or readily available publication which adequately describes the subject matter.

(k) Abstract of the Disclosure: See MPEP § 608.01(f). A brief narrative of the disclosure as a whole in a single paragraph of 150 words or less commencing on a separate sheet following the claims. In an international application which has entered the national stage (37 CFR 1.491(b)), the applicant need not submit an abstract commencing on a separate sheet if an abstract was published with the international application under PCT Article 21. The abstract that appears on the cover page of the pamphlet published by the International Bureau (IB) of the World Intellectual Property Organization (WIPO) is the abstract that will be used by the USPTO. See MPEP § 1893.03(e).

2. Claim 3 objected to because of the following informalities: the preamble of uses the term "splitting" when referring to element 21 in Fig. 1, yet, in the specification, on page 5 line 28, element 21 is referred to as "subtractor". Appropriate correction is required.

Drawings

1. The drawings are objected to under 37 CFR 1.83(a). The drawings must show every feature of the invention specified in the claims. Therefore, the steps of the claims must be shown or the feature(s) canceled from the claim(s). No new matter should be entered.

2. Claim 7 is objected to because of typographical errors in the dependency.

Appropriate correction is required. Claim 7 should depend on claim 3.

Claim Rejections - 35 USC § 102

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

4. Claims 1-8 are rejected under 35 U.S.C. 102(b) as being anticipated by Dahlgren et al. (IEEE-95).

As to claims 1 and 8, Dahlgren et al. teach

splitting the target spectrum in at least a first part and a second part (breaking transfer function model into two parts, page 437 ARMA Model left column first paragraph);

using a first model operation (b_k coefficients are set to zero, except b_o=1) on the first part of the target spectrum (ARMA model, linear difference equation) to obtain auto-regressive parameters (the AR model can be extracted from ARMA model (linear difference equation) if all the b_k coefficients are set to zero, except b_o=1, page 437 ARMA Model left column first paragraph).

using a second model operation (a_k coefficients are set to zero, except a_o=1) on the second part of the target spectrum (ARMA model, linear difference equation) to obtain moving-average parameters (The MA model is extracted from the ARMA model

(linear difference equation) by setting all of the a_k coefficients are set to zero, except a_0=1, page 437 ARMA Model left column first paragraph); and

combining the auto-regressive parameters (sharp peaks) and the moving average (deep valleys) parameters (ARMA) to inherently obtain the filtered parameters (the AR model is appropriate for spectra containing sharp peaks, the MA model is appropriate for spectra that contains deep valleys, the combined ARMA model contains both of these extremes, sharp peaks and deep valleys, page 437 ARMA Model right column first paragraph)

As to claim 2, Dahlgren et al. teach

using the first modeling operation on an inherent reciprocal of the second part of the target spectrum (page 437, ARMA modeling, equation 5; AR modeling process, the first part, is inherently the reciprocal of the MA modeling process, or the second part because the AR process involves the all-pole model and the MA modeling process involves the opposite or reciprocal, the all-zero model).

As to claim 3, Dahlgren et al. teach

taking an initial split in an initial first part and an initial second part (breaking transfer function model into two parts, page 437 ARMA Model left column first paragraph, the two parts are inherently the initial split of the fist part, AR, and second part, MA) ; and

using an iterative procedure to obtain a better split than the initial split until a threshold value is met (Maximum likelihood estimation, page 437 right column second paragraph, equation 6-9, the Akaike information criterion is an estimator for the AR and MA models in equations 6-7).

As to claim 4, Dahlgren et al. teach

using a first modeling operation on a first part of a previous split to obtain new auto-regressive parameters (equations 7-8 page 437);

using a second modeling operation on a second part of a previous split to obtain new moving-average parameters (equations 6 and 8 page 437);

inherently re-attributing parts of the first part of the previous split that could be modeled accurately by the first modeling operation to the second part of the previous split (ARMA, page 437 ARMA Modeling left column first paragraph)

As to claim 5, Dahlgren et al. teach

inherently dividing the first part of the previous split by an estimate of the target spectrum based on moving-average parameters (MLE, maximum likelihood estimation of noise for ARMA, which inherently includes the MA parameters page 437 right column second paragraph);

inherently dividing the second part of the previous split by an estimate of the target spectrum based on auto-regressive parameters (AIC is a good estimator for the

AR and MA, page 437, equations 6-9, ARMA Modeling, right column, second paragraph).

As to claim 6, Dahlgren et al. teach

an inherent initial first part comprises at least a significant part of the target spectrum above a mean logarithmic level and the inherent initial second part comprises at least a significant part below said level (MLE, maximum likelihood estimation of noise for ARMA, which inherently includes the MA parameters page 437 right column second paragraph; MLE inherently would divide the data falling into parts below a given standard and above a given standard);

As to claim 7, Dahlgren et al. does not teach splitting via a mapping function.

However, Official Notice is taken that calculating a mapping function is well-known in repeated patterns or periodic functions in order to accurately calculate the parameters within a given domain, thus at the time of the invention, it would have been obvious to one of ordinary skill in the art to implement a mapping function as a design option in order to estimate better parameters, thus avoiding errors in partitioning the designed parameters.

Claim Rejections - 35 USC § 103

5. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. Claims 9-10 are rejected under 35 U.S.C. 103(a) as being unpatentable over Dahlgren et al. (IEEE-95) in view of Bloebaum et al. (6,070,137).

As to claims 9 and 10 Dahlgren teach

the step of modeling comprising:

splitting the target spectrum in at least a first part and a second part (breaking transfer function model into two parts, page 437 ARMA Model left column first paragraph);

using a first model operation (b_k coefficients are set to zero, except b_o=1) on the first part of the target spectrum (ARMA model, linear difference equation) to obtain auto-regressive parameters (the AR model can be extracted from ARMA model (linear difference equation) if all the b_k coefficients are set to zero, except b_o=1, page 437 ARMA Model left column first paragraph).

using a second model operation (a_k coefficients are set to zero, except a_o=1) on the second part of the target spectrum (ARMA model, linear difference equation) to obtain moving-average parameters (The MA model is extracted from the ARMA model (linear difference equation) by setting all of the a_k coefficients are set to zero, except a_o=1, page 437 ARMA Model left column first paragraph); and

combining the auto-regressive parameters (sharp peaks) and the moving average (deep valleys) parameters (ARMA) to inherently obtain the filtered parameters (the AR model is appropriate for spectra containing sharp peaks, the MA model is

appropriate for spectra that contains deep valleys, the combined ARMA model contains both of these extremes, sharp peaks and deep valleys, page 437 ARMA Model right column first paragraph)

modeling a spectrum of the noise by determining filter parameters of a filter which has a frequency response approximating the spectrum of the noise (page 437 right col. first paragraph, modeling a filter based on noise is inherent in MA process).

Dahlgren teach approximating modeling a filter based on noise (page 437 right col. first paragraph).

Dahlgren does not explicitly teach modeling a filter based on spectral subtraction or noise reconstruction.

However, Bloebaum teach

modeling a spectrum of the noise by determining filter parameters of a filter which has a frequency response approximating the spectrum of the noise (MBE, mixed band excitation, models background noise, in frequency domain, col. 5 lines 21-33, col. 2 lines 20-26).

subtracting the reconstructed noise from the audio signal to obtain a noise-filtered audio signal (spectral estimator, subtracts portion of the noise power spectral density fro current speech power spectral, col. 3 lines 21-31);

At the time of the invention, it would have been obvious to one of ordinary skill in the art to implement AR and MA techniques with Bloebaum's adaptive spectral enhancement filtering technique in order to reduce the variance in of the noise estimate, as taught by Bloebaum, col. 5 lines 27-35.

7. Claims 11 and 13 are rejected under 35 U.S.C. 103(a) as being unpatentable over Dahlgren et al. (IEEE-95) in view of Miseki et al. (6,167,375).

As to claims 11 and 13,

Dahlgren teach

the steps (necessary in ARMA) modeling comprising:

splitting the target spectrum in at least a first part and a second part (breaking transfer function model into two parts, page 437 ARMA Model left column first paragraph);

using a first model operation (b_k coefficients are set to zero, except b_o=1) on the first part of the target spectrum (ARMA model, linear difference equation) to obtain auto-regressive parameters (the AR model can be extracted from ARMA model (linear difference equation) if all the b_k coefficients are set to zero, except b_o=1, page 437 ARMA Model left column first paragraph).

using a second model operation (a_k coefficients are set to zero, except a_o=1) on the second part of the target spectrum (ARMA model, linear difference equation) to obtain moving-average parameters (The MA model is extracted from the ARMA model (linear difference equation) by setting all of the a_k coefficients are set to zero, except a_o=1, page 437 ARMA Model left column first paragraph); and

combining the auto-regressive parameters (sharp peaks) and the moving average (deep valleys) parameters (ARMA) to inherently obtain the filtered parameters (the AR model is appropriate for spectra containing sharp peaks, the MA model is appropriate for spectra that contains deep valleys, the combined ARMA model contains

both of these extremes, sharp peaks and deep valleys, page 437 ARMA Model right column first paragraph; the ARMA includes the combination of AR and MA).

Dahlgren does not explicitly teach modeling waveform parameters.

However, Miseki et al. teach

determining basic waveforms in the audio signal (CELP, col. 2 lines18, 49-51);

obtaining a noise component from the audio signal by subtracting the basic waveforms from the audio signal (CELP, suppresses distortion of a waveform, col. 2 lines 51-55, suppression of the distortion of waveform is necessarily subtracting or removing the distortion or noise portion of the waveform).

modeling a spectrum of the noise component by determining filter parameters of a filter which has a frequency response approximating the spectrum of the noise component (Fig. 17-18 and col. 23 lines 21-35; the predictor estimates the spectral shape, thus modeling the spectrum, Fig. 18 is the noise encoder of Fig. 15, thus modeling the spectrum of noise, via filter parameters such as AR, MA, or ARMA used in the predictor, element 547, of Fig. 18);

including the filter parameters (AR, MA, or ARMA) and waveform parameters (CELP) representing the necessary basic waveforms in an encoded audio signal (col. 2 line 51 and col. 23 lines 20-26).

At the time of the invention, it would have been obvious to one of ordinary skill in the art to model waveform parameters via AR, MA, or ARMA parameters in order to easily obtain background noise with less bits by encoding the components after

converting them into parameters in the frequency domain or transform domain, as taught by Miseki et al., col. 2 lines 50-58.

8. Claims 12, 14-17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Dahlgren et al. (IEEE-95) in view of Miseki et al. (6,167,375) in further view of Atsmon et al. (6,607,136 benefit of provisional application 60/153,858)

As to claim 12 and 14,

Dahlgren teaches all the limitations of claim 11.

Dahlgren does not explicitly teach decoding an audio signal.

However, Miseki et al. teach encoding and decoding of audio signals (Abstract) which includes the method and means for

filtering a white noise signal (background noise) to necessarily obtain reconstructed noise component, which filtering is determined by the filter parameters (col. 23 lines 21-35 and col. 1 lines 8-13).

synthesizing basic waveforms based on the waveform parameters (CELP, col. 2 lines 51-55; CELP well known for synthesizing speech signals or waveforms)

adding the reconstructed noise component to the synthesized basic waveform to obtain a decoded audio signal (col. 25 lines 51-67; adding the reconstructed noise component is a necessary reconstruction process of a synthesized waveform).

At the time of the invention, it would have been obvious to one of ordinary skill in the art to decode speech for efficiency in reconstructing the original signal waveform, wherein a speech signal including background noise is encoded by compressing it

efficiently in a state which is as close to the original signal speech as possible, as taught by Miseki et al., col. 1 lines 8--13.

Neither Dahlgren et al. nor Miseki et al. explicitly teach implementing an audio player.

However, Atsmon et al. teach audio player (col. 35 lines 10-11).

At the time of the invention, it would have been obvious to one of ordinary skill in the art to implement audio signal technique in an audio player for transmission of data streams, thus if sound is utilized a conventional audio file is played by a software audio player as is known in the art, as taught by Atsom et al. (col. 35 lines 5-11).

As to claim 15,

Neither Dahlgren et al. nor Miseki et al. explicitly teach implementing an audio player.

However, Atsmon et al. teach audio player (col. 35 lines 10-11).

At the time of the invention, it would have been obvious to one of ordinary skill in the art to implement audio signal technique in an audio player for transmission of data streams, thus if sound is utilized, a conventional audio file is played by a software audio player as is known in the art, as taught by Atsom et al. (col. 35 lines 5-11).

As to claim 16

Dahlgren et al. does not teach waveform coding.

However, Miseki et al. teach

Miseki et al. teach

waveforms parameters representing basic waveforms (CELP, col. 2 lines18, 49-51);

a spectrum of the noise component represented by a combination of autoregressive parameters and moving average parameters (col. 23 lines 21-35 and col. 2 line 51 and col. 23 lines 20-26; the predictor estimates the spectral shape, thus modeling the spectrum, Fig. 18 is the noise encoder of Fig. 15, thus modeling the spectrum of noise, via filter parameters such as AR, MA, or ARMA used in the predictor, element 547, of Fig. 18, thus the ARMA includes the combination of AR and MA).

At the time of the invention, it would have been obvious to one of ordinary skill in the art to model waveform parameters via AR, MA, or ARMA parameters in order to easily obtain background noise with less bits by encoding the components after converting them into parameters in the frequency domain or transform domain, as taught by Miseki et al., col. 2 lines 50-58.

As to claim 17,

Dahlgren et al. does not explicitly teach implementing a storage medium for the encoded audio signal.

However, Miseki et al. teach

a storage medium on which an encoded audio signal is stored (col. 27, lines 53-57).

At the time of the invention, it would have been obvious to one of ordinary skill in the art to store encoded audio signals in order for updating, thus the output is stored in a buffer to update the same in preparation for the input of the spectral shape of the next frame, as taught by Miseki et al., col. 27, lines 53-57.

Conclusion

9. The following art made of record and not relied upon is considered pertinent to applicant's disclosure Romesburg et al. (6,160,886); Seza et al. (5,553,194); and Eatwell (5,742,694).

Romesburg et al. teach echo suppression.

Seza et al. teach encoder unit includes AR and MA codebooks vocoder device.

Eatwell teaches noise reduction for enhancing noisy audio signals.

Tosaya et al. teach audible and inaudible voice recognition.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Myriam Pierre whose telephone number is 571-272-7611. The examiner can normally be reached on Monday – Friday from 5:30 a.m. - 2:00p.m.

10. If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Richemond Dorvil can be reached on (571) 272-7602. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

11. Information as to the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

05/11/2005

Vijay B Chawan

VIJAY CHAWAN
PRIMARY EXAMINER

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Sheet 1 of 1

Form PTO-1449 U.S. DEPARTMENT OF COMMERCE (REV. 7-80) PATENT AND TRADEMARK OFFICE	Atty. Docket No. NL 000287	Serial No. 10/031,024
	Applicant ALBERTUS C. DEN BRINKER ET AL.	
INFORMATION DISCLOSURE CITATION (Use several sheets if necessary)	Filing Date 1/14/02	Group 2654

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	AG							
	AH							
	AI							
	AJ							
	AK							

OTHER (Including Author, Title, Date, Pertinent Pages, Etc.)

MP	AL	Petre Stoica et al., "Introduction to Spectral Analysis," Prentice-Hall Inc., 1997, pages 101-108.
	AM	
	AN	

Examiner	Date Considered 6-23-05

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include a copy of this form with next communication to applicant.

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531 Rec'd PCT/PTO 14 JAN 2002

Form PTO-1449 U.S. DEPARTMENT OF COMMERCE
(REV. 7-80) PATENT AND TRADEMARK OFFICE

Atty. Docket No. NL 000287

Serial No. 10/031024

Applicant

ALBERTUS C. DEN BRINKER ET AL.

Filing Date CONCURRENTLY

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MP	AB	5 9 4 3 4 2 9	8/24/99	HANDEL	381	94.1	
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	AE						
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		Document Number	Date	Country	Class	Sub-class	Trans. Yes	Trans. No
MP	AG	W O 9 7 2 8 5 2 7	07.08.97	PCT (WORLD)	G10L	3/01		
	AH							
	AI							
	AJ							
	AK							

OTHER (Including Author, Title, Date, Pertinent Pages, Etc.)

	AL		
	AM		
	AN		

Examiner

Date Considered 6-23-05

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP Draw line through citation if not in conformance and not considered. Include a copy this form with next communication to applicant.

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Notice of References Cited	Application/Control No. 10/031,024	Applicant(s)/Patent Under Reexamination DEN BRINKER ET AL.	
	Examiner Myriam Pierre	Art Unit 2654	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,070,137	05-2000	Bloebaum et al.	704/227
*	B	US-6,167,375	12-2000	Miseki et al.	704/229
*	C	US-6,607,136	08-2003	Atsmon et al.	235/492
*	D	US-6,160,886	12-2000	Romesburg et al.	379/406.05
*	E	US-5,553,194	09-1996	Seza et al.	704/221
*	F	US-5,742,694	04-1998	Eatwell, Graham P.	381/94.2
*	G	US-6,487,531	11-2002	Tosaya et al.	704/246
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	Dahlgren, S.W. et al., Radar Detection via ARMA Modeling, 12-14 March 1995, Proceedings of the Twenty-Seventh Southeastern Symposium, IEEE, pages 436-440.
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Radar Signal Detection Via ARMA Modeling

S.W. Dahlgren, N.H. Younan, and B.J. Skinner

Department of Electrical and Computer Engineering
Mississippi State, MS 39762

Abstract

In this paper, a phase-shift keyed (PSK) spread spectrum radar signal is analyzed using autoregressive moving-average (ARMA) spectral estimation techniques. In general, the ARMA model achieves better PSD estimates and higher resolution than the traditional techniques. Results for simulated spread spectrum radar signals of various lengths in additive white Gaussian noise are presented and a comparison with traditional PSD techniques is made to ascertain the validity of the ARMA model.

Introduction

In general, radar signals can be easily detected from the PSD via the standard fast Fourier transform (FFT) implementation as long as it is first order periodic, a signal with additive sine wave components [1]. For second order periodic or cyclostationary signals, i.e., spread spectrum radar signals, the detection process from the PSD directly is not quite effective. A common way to extract useful information within the signal from the PSD is to regenerate the harmonic content via a second order transformation such as squaring [2]. However, this technique is applicable only for waveforms with a moderate signal-to-noise ratio (SNR) [3]. When the noise level is high compared to the signal, i.e., low SNR, spurious peaks may occur in the PSD leading to false signal detection.

To improve the detection of spread spectrum radar signals, the autoregressive-moving average (ARMA) spectral estimation technique is investigated in this paper. The ARMA model, in general, has more degrees of freedom than any other parametric model. It is characterized by its ability to achieve better PSD estimators and better spectral resolution than the ones obtained from the classical techniques. In addition, it is nearly always the appropriate one to use for noisy data. The accuracy of the ARMA model is based upon choosing an appropriate model order. Since the model order depends upon the characteristics of the data being analyzed, the Akaike information criterion (AIC) is found to be suitable for radar signal analysis.

Signal Description and Receiver Model

The PSK spread spectrum signal

$$s(t) = \sum_{n=-\infty}^{\infty} a_n \Pi\left(\frac{t-nT}{T}\right) \cdot \cos(2\pi f_c t + \varphi) \qquad (1)$$

is processed via the receiver model shown in Figure 1. This model is adapted from [3], in which the PSK signal is analyzed using classical techniques. The receiver, in this case, consists of a preselection bandpass filter and a lag product device followed by a high pass filter to remove the baseband terms.

The signal is generated in white Gaussian noise with zero-mean and 20 dB SNR. The preselection filter is a 5th order Butterworth filter with a bandwidth of $.4/t_s$, where the sampling rate, t_s, was chosen to be unity. The filter order and bandwidth is chosen arbitrarily. The lag product device represents the transformation used to reveal the timing information from the second order periodic or cyclostationary signal. After the signal passes through the lag product device, it is high pass filtered. The high pass filter is a 2nd order Butterworth filter with a bandwidth chosen to be $.4/t_s$ to remove the baseband terms introduced by the lag product device.

The generated PSK signal consists of 32 chips, with each chip consisting of 32 samples/chip. The carrier frequency of the PSK signal is determined such that there are four cycles of the carrier in each chip. Each term of the random PSK sequence, a_n, is equally likely to be either ±1.

The expected value of the PSK signal out of the lag product device is

$$E\{s_s(t)\} = \sum_{n=-\infty}^{\infty} \Pi\left(\frac{t-nT}{T/2}\right) \cdot \cos(2\pi f_c t + \varphi)\cos(2\pi f_c (t+T/2) + \varphi) \qquad (2)$$

and its Fourier transform is given by [3]

$$F\{E\{s_e(t)\}\} = \frac{T}{4}\cdot \mathrm{sinc}\left(\pi f_c \frac{T}{2}\right)\cdot \cos\left(2\pi f_c \frac{T}{2}\right)\cdot \sum_{n=-\infty}^{\infty}\delta(f - nT)$$
$$+\frac{T}{8}\cdot\left[\mathrm{sinc}\left(\pi(f-2f_c)\frac{T}{2}\right)e^{j(\pi f_c T + 2\phi)} \sum_{n=-\infty}^{\infty}\delta(f - \frac{n}{T} - 2f_c)\right]$$
$$+\frac{T}{8}\cdot\left[\mathrm{sinc}\left(\pi(f+2f_c)\frac{T}{2}\right)e^{-j(\pi f_c T + 2\phi)} \sum_{n=-\infty}^{\infty}\delta(f - \frac{n}{T} + 2f_c)\right] \tag{3}$$

where T is the pulse duration, and f_c is the carrier frequency of the PSK signal. The corresponding spectrum is shown in Figure 2 where the timing information (pulse duration and carrier frequency) can be determined from the location of the spectral lines. Therefore, it is desirable to utilize a method of spectral estimation to determine the location of the spectral lines.

ARMA Modeling

Parametric modeling for spectral estimation consists of choosing an appropriate model, estimating the parameters of the model, and determining the PSD of the model using the estimated parameters and the theoretical PSD expression [4]. ARMA modeling, for which the autoregressive (AR) and moving average (MA) models are a special case, is a time series or rational transfer function model. The ARMA model is defined by the linear difference equation [4]

$$x(n) = -\sum_{k=1}^{p} a_k x(n-k) + \sum_{k=0}^{q} b_k u(n-k) \tag{4}$$

where $u(k)$ is the input driving sequence and $x(n)$ is the resulting output sequence. The transfer function relating the input and output sequences for the ARMA model is

$$H(z) = \frac{\sum_{k=0}^{q} b_k z^{-k}}{1 + \sum_{k=1}^{p} a_k z^{-k}} \tag{5}$$

This model is sometimes referred to as a *pole-zero model* and is denoted as an *ARMA(p,q)* model. The above transfer function model can be broken into two parts, an AR model and a MA model. The MA model is extracted from the ARMA model by setting all of the a_k coefficients to zero, except $a_0 = 1$. The resulting difference equation

$$x(n) = \sum_{k=0}^{q} b_k u(n-k) \tag{6}$$

defines the *all-zero model* and is denoted as a *MA(q)* process. The AR model can be extracted in a similar manner from the ARMA model if all the b_k coefficients are set to zero, except $b_0 = 1$. The resulting difference equation is

$$x(n) = -\sum_{k=1}^{p} a_k x(n-k) + u(n) \tag{7}$$

where the sequence $x(n)$ is a linear regression of terms on itself. The above AR process is termed an *all-pole model* and is denoted as an *AR(p)* process.

The selection of an appropriate model is an important part of parametric modeling and spectral estimation. In order to obtain an accurate spectral estimate, only as few of the models parameters as necessary should be left to be estimated. Some general rules in selecting the appropriate model can be determined from the characteristics of the models being used. The AR model is appropriate for spectra containing sharp peaks, i.e., narrowband signals. The MA model is appropriate for spectra that contains deep valleys, i.e., wideband signals. The combined ARMA model can be used to represent both of these extremes, sharp peaks, and deep valleys [4]. Both the AR and ARMA models are investigated in this paper.

Once the proper model is determined, the problem of choosing the order of the model arises. The accuracy of the chosen model is based upon choosing an appropriate model order. Too low of an order may result in a smoothed spectrum estimate, and too high of an order estimate may result in a spectrum with spurious peaks. Since the model order depends upon the characteristics of the data being analyzed, a priori knowledge of the signal or data being analyzed may sometimes be of use. If little or no knowledge of the data is available, a model order estimator such as the Akaike information criterion (AIC) is generally considered to be a good estimator. The AIC for an AR model is defined by

$$AIC(k) = N \ln(\hat{\sigma}^2_k) + 2k \tag{8}$$

where $\hat{\sigma}^2_k$ is the estimate of the white noise variance for the *kth* order AR model, and N is the length of the given data sequence. The AIC is similarly defined for an ARMA model as

$$AIC(i,j) = N \ln(\hat{\sigma}_{i,j}^2) + 2(i+j) \tag{9}$$

where $\hat{\sigma}_{i,j}^2$ is maximum likelihood estimation (MLE) of the noise variance for the assumed ARMA(i,j) model order. The AIC is calculated for all orders of interest and the order that minimizes this criterion is chosen as the appropriate model order.

Simulation Results

Multiple realizations of the noise contaminated PSK signal are simulated using the system in Figure 1. The

expected spectrum from the receiver is shown in Figure 2 and is given by Equation (3). The signals are generated using a unity sampling rate with chip rates and durations as mentioned above. The signals are generated separately for both 128 and 512 point sequences using zero-mean white Gaussian noise. The signals are prefiltered, transformed through the lag product device, and then postfiltered to remove some baseband terms. The results from the received PSK signal are shown in Figure 3 and 4 for the 128 and 512 point sequences, respectively.

Figure 3 represents the spectrum of the received PSK signal using the classical, AR, and ARMA spectral estimation techniques on a 128 point sequence. In each of the spectrum plots in Figure 3, the spectral lines predicted by Equation (3) at twice the carrier frequency are clearly seen. The spectral lines due to the chip rate frequencies are clearly resolved for the classical and AR spectral estimation techniques in this realization. The ARMA model failed to resolve the spectral line predicted by Equation (3) at $2f_c - 1/T$, but did resolve its mirrored peak at $2f_c + 1/T$. The classical and AR models both resolved the spectral peaks predicted by Equation (3) for the given realization, but the ARMA model and the classical technique failed to remain consistent on all of the realizations tested.

Figure 4 represents the spectrum of the received PSK signal using the classical, AR, and ARMA spectral estimation techniques on a 512 point sequence. The spectral lines at twice the carrier frequency and at integer multiples of the chip rates can be seen in each of the plots as predicted by Equation (3) and Figure 2. The structure of the ARMA and AR spectral estimates are seen to be similar to the classical techniques spectral estimates. The classical spectral estimation technique can be seen to resolve its spectral information hidden by other spurious spectral peaks between the chip rate frequencies and carrier frequency for this realization. Both the ARMA and AR models correctly identified the carrier frequency and the chip rate frequencies in the PSK signal for the given realization in Figure 4. The ARMA and AR model order estimators typically chose model orders in the area of ARMA(10,6) and AR(18) model orders. The AR model consistently identified the spectral peaks in each of the realizations tested. The ARMA model and classical techniques both falsely identified information in some of the realizations tested. The AIC model order selection criterion for the ARMA model is thought to have determined too small of an order for the number of poles in the transfer function model due to the ill-conditioned data. The under estimation of the number of poles in an ARMA model can cause the calculated spectrum to combine spectral peaks or smooth the overall spectral estimate and thus cause false information to appear in the spectrum.

Figure 5 represents a statistical average of ten separate realizations of the spectral estimate using the classical, ARMA, and AR spectral estimation techniques for the 128 and 512 point sequences, respectively. The classical and AR spectral estimation techniques can be seen to resolve all of the needed spectral information on the average for the 128 point sequence. The ARMA model can be seen to resolve the carrier frequency, but not the chip rate frequencies for the 128 point sequences on the average. In each of the plots for the 512 point sequences, it is seen that each of the techniques used resolve the needed spectral information on the average. The AR spectral estimation technique is seen to provide highest resolution and consistency on the average for the ten realizations tested.

Conclusions

In this paper, three different techniques for determining the spectrum of a spread spectrum radar signal are compared. The classical technique of determining a signals spectrum via the FFT proved to provide the needed information hidden in many smaller spectral peaks caused by noise and filtering. The classical technique also falsely identified the chip rate frequency in some of the realizations analyzed. The ARMA model is seen to provide an accurate spectral estimate for the given realizations, but may also falsely identify the spectral information when the data is either ill-conditioned or too short. The AR model, which is a special case of the ARMA model, proves to provide an accurate and more readable spectral estimate than either of the previous methods discussed. The spectral peaks in the AR model were clearly resolved in each of the cases tested. The noise in the ARMA and AR spectral estimates is seen to be smoothed as compared to that of the classical technique. The ARMA and AR spectral estimates are seen to have a similar spectral estimate to that of the FFT while providing a much clearer spectral portrait. ARMA spectral estimation techniques have proven to be a valid and useful tool in analyzing spread spectrum radar signals.

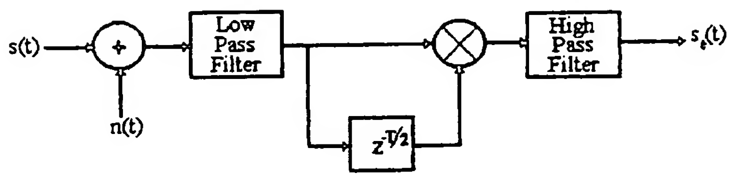

Figure 1. Block diagram of the receiver used to process the PSK signal.

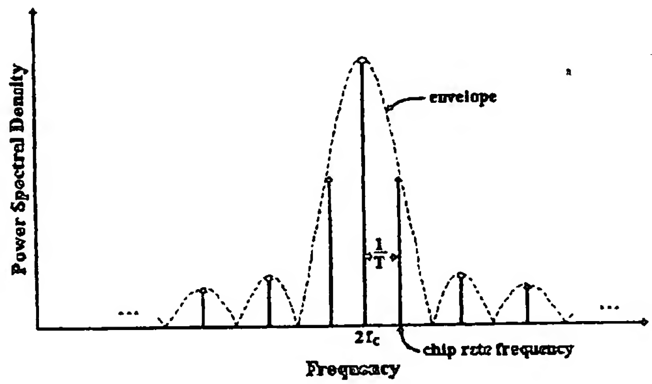

Figure 2. Expected waveform for the Fourier transform of the output from the lag product device.

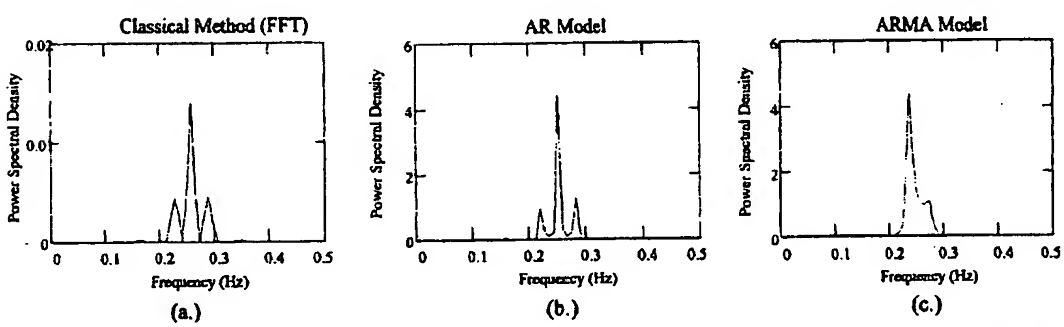

Figure 3. Spectrum plots of the received PSK signal using FFT, AR, and ARMA spectral estimation techniques on a 128 point sequence. (a.) Spectrum of the received PSK signal using classical techniques. (b.) Spectrum of the received PSK signal using the AR model. (c.) Spectrum of the received PSK signal using the ARMA model.

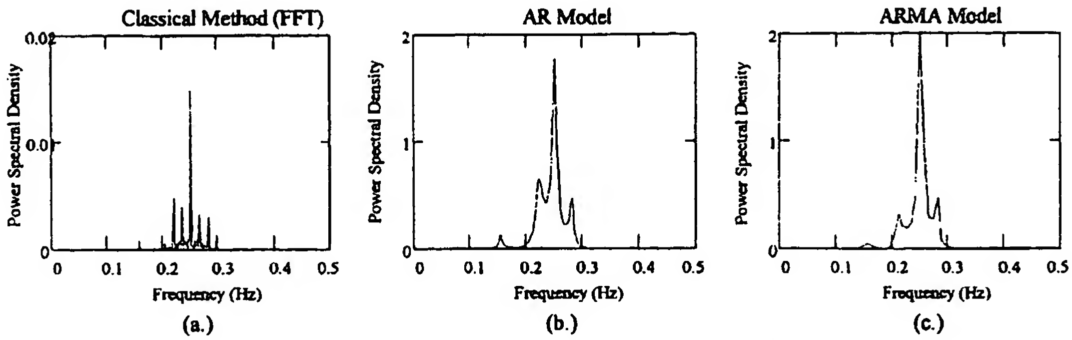

Figure 4. Spectrum plots of the received PSK signal using FFT, AR, and ARMA spectral estimation techniques on a 512 point sequence. (a.) Spectrum of the received PSK signal using classical techniques. (b.) Spectrum of the received PSK signal using the AR model. (c.) Spectrum of the received PSK signal using the ARMA model.

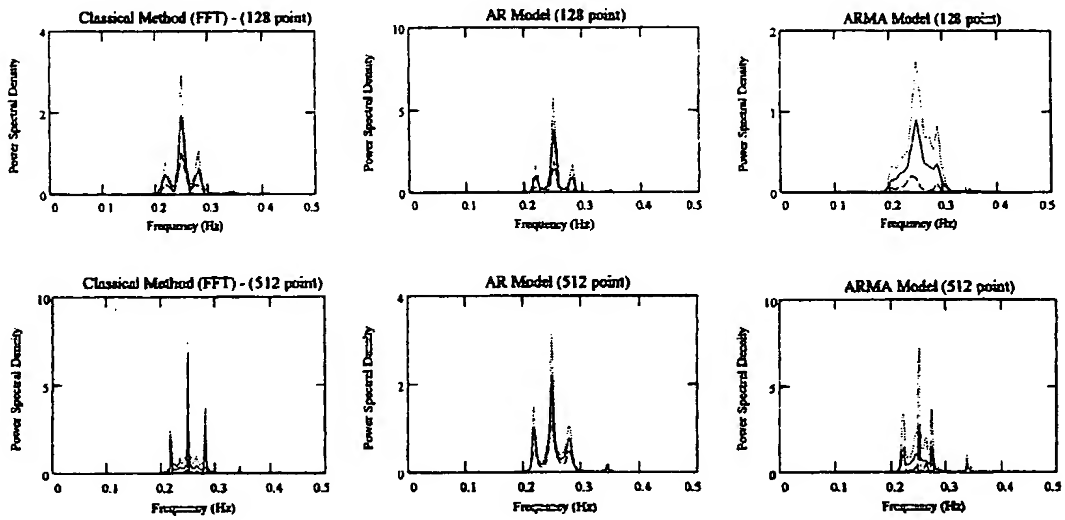

Figure 5. Plot of the mean and mean ± standard deviation of the spectral estimates using the classical, AR, and ARMA spectral estimation techniques over 10 independent realizations of a 128 and 512 point sequence, respectively.

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